THE OCCURRENCE OF CRETACEOUS SEDIMENTS IN SOUTH-WESTERN VICTORIA

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Abstract

Dicotyledonous leaves occur in association with leaves of exclusively Mesozoic plants in a fossil flora collected from the Runnymede Formation at Killara Bluff, near Casterton. This flora indicates a Cretaceous age for the beds. The Runnymede Formation occurs at the top of lacustrine Mesozoic sediments (Merino Group) in the Killara Bluff area, and is unconformably overlain by marine sediments of Palaeocene or Lower Eocene age (Bahgallah Formation).

The stratigraphic relations of the Runnymede Formation are described; and the distribution, age, and lithology of the Merino Group in south-western Victoria are discussed. The Merino Group was formerly regarded as entirely of Jurassic age.

Introduction

Lacustrine mudstones and felspathic sandstones (arkoses) of Mesozoic age outcropping around Merino, Casterton, and Coleraine in south-western Victoria form one of the main occurrences of Mesozoic sediments in the State. Apart from small occurrences of Triassic sediments at Bacchus Marsh and Campbelltown, the Victorian Mesozoic deposits have generally been attributed to the Jurassic since about the year 1900, and Medwell (1954a) has recently shown that they are predominantly of Lower Jurassic age. Several accounts of the Jurassic rocks of the State (Skeats, 1935; Edwards and Baker, 1943; David and Browne, 1950) include brief descriptions of the Mesozoic deposits of the south-west. However, the presence of two angiosperm leaves among the fossil plants recently collected from Mesozoic sediments at Killara Bluff, seven miles south of Casterton, suggests that Cretaceous sediments occur in this area. Determinations of the complete fossil macroflora made by Miss L. M. Medwell (formerly of the School of Geology, University of Melbourne) confirm this conclusion, and show that these beds are probably of Lower Cretaceous age (Medwell, 1954b). This is the first record of Cretaceous rocks in Victoria, although David and Browne (1950, p. 514) have suggested that western Victoria was probably the site of a lake in Cretaceous time.

The Mesozoic sediments of south-western Victoria comprise a major lithological unit for which the term Merino Group (Hills, Teichert and Thomas, 1952) has been adopted. In this paper present knowledge of the Merino Group is reviewed, and new evidence relating to the age and stratigraphy of the upper part of the Group is brought forward.

Distribution and Thickness of the Merino Group

An outline of the approximate area occupied by Merino sediments is given in Fig. 1. The map is based on the Victorian Geological Survey eight miles to one inch geological map of the State (Murray, Stirling et al., 1902), with amendments from the detailed mapping of Caldwell (1930-1932) and the more recent work of the Survey (1949-1952).
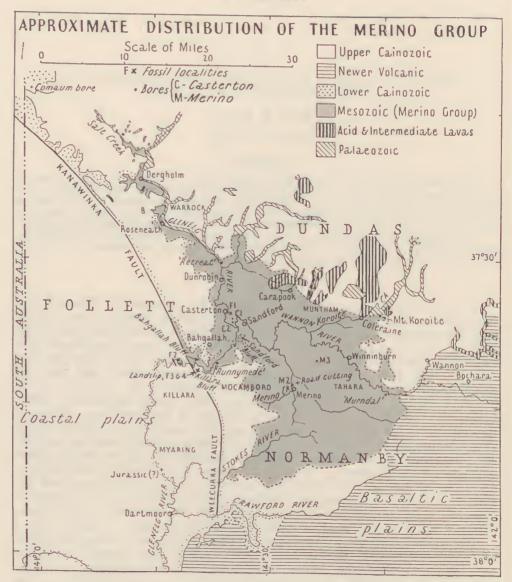
Fig. 1

The main exposures are in the valleys of the Glenelg, Wannon and Stokes Rivers and their tributaries, the outcrops being distributed over a roughly triangular area the centre of which is in the vicinity of Merino. The interfluves in this area are generally tablelands where the Merino Group is capped by a thin deposit of lateritized Cainozoic sands and gravels. The laterites are fossil soils (Dunn, 1912, p. 113; Hills, 1939, p. 302; Blackburn and Leslie, 1949) which transgress the bedding in the Cainozoic sediments (Hills, 1939, p. 302) and therefore do not constitute a true stratigraphic rock unit. They have generally been referred to informally as the "Dundas laterites".

A fringe of marine Lower Tertiary sediments with a maximum thickness of about a hundred feet caps the Merino Group along the western edge of the triangle, which is bounded on this side by the Kanawinka and Weecurra faults (Boutakoff, 1952). These and associated faults bring the Merino Group against the thick Cainozoic sediments of the coastal plains of County Follett and County Normanby. In the south-east and east the Merino Group passes beneath Tertiary sediments and the Newer Volcanics of the Western District basaltic plains. Skeats (1935, p. 125) has suggested that it may be continuous beneath the basalts with the Mesozoic deposits of the Otways area, as fragments of "Jurassic" sediments occur among the ejectamenta of some of the Western District volcanoes. In the north and north-east the Mesozoic abuts unconformably on Palaeozoic sedimentary, meta-morphic, and igneous rocks in County Dundas and the northern part of County Follett. The junction of the Merino Group with these older rocks outcrops in a line passing through Coleraine, Carapook and Retreat, which may in part mark the line of a fault or monoclinal flexure (see Structure). A small inlier of mica schists and gneisses containing veins of pegmatite occurs on the Wannon River at Winninburn, south of Coleraine.

The Merino Group presumably continues beneath the Cainozoic sediments to the south and south-west of the Kanawinka fault, but excepting outcrops in the Glenelg valley in the neighbourhood of Killara Bridge the only record of definite Mesozoic sediments in this region is from a bore at Robe (South Australia) in which they were first encountered at a depth of about 1,468 ft., and were still being drilled when boring ceased at 4,504 ft. (Ward, 1917, 1926). The outcrops in the bed of the Glenelg River shown as Jurassic on the Mines Department parish plan of Myaring (Kenny and McEachern, 1937) have now been shown to belong to the same formation as the "Oligocene" sands and ligneous clays of the Dartmoor area.

The Merino Group also extends beneath a cover of younger rocks to the north-west of the main triangular area and has been recognized in outcrops on Salt Creek, north of Dergholm (Caldwell, 1941); in samples from the original Comaum bore in Victoria (Allotment 50, Parish of Langkoop; approx. depth to Merino Group 575 ft.); and from the recent bore at Comaum in South Australia (Cookson, 1953. Bore in section 222, Hundred of Comaum; approx. depth to Merino Group 650 ft.).

Two bores in the main area pass through more than 900 ft. of Merino sediments (Merino No. 2, 909 ft.; Merino No. 3, 959 ft. Department of Mines, Victoria, 1898, p. 20; 1938, p. 28), and several others have penetrated over 500 ft. of these beds; but as yet Palaeozoic bedrock has not been intersected in bores within this area. The Merino No. 2, and Casterton Nos. 1 and 2 bores (Department of Mines, Victoria, 1938, pp. 34, 138), penetrating 909 ft., 758 ft. and 725 ft. of Merino sediments respectively, are situated on creek and river flats several hundred feet

below the level of the surrounding tablelands, and as dips in these areas appear to be low, the total thickness of the Merino Group at Merino and Casterton is at least a thousand feet and may be much greater.

Age of the Merino Group

PREVIOUS AGE EVIDENCE

Organic remains recorded from the Merino Group are few in number and come from widely scattered localities, some of which are difficult to locate precisely. The following occurrences are cited in the literature.

Mesozoic fossils in south-western Victoria were first discovered by Selwyn in April 1860 (Selwyn, 1862, p. 13). Selwyn found specimens of *"Taeniopteris Daintreei"* McCoy "in the banks of the Wannon opposite Mr. S. Winter's house, about six miles south-west of Bochara." Mr. Samuel P. Winter's homestead, "Murndal", was situated in the Spring Valley Pre-Emptive Right, Parish of Murndal, and it is probable that other records of *"T. Dantreei"* from "Murndal on the Wannon River" (McCoy, 1875, p. 16; Tenison-Woods, 1883, p. 117; Chapman, 1908, p. 215, etc.) also refer to this locality.

Later in the same year (1860) specimens of a new species of freshwater mussel were found by Mr. E. Dacomb in soft greenish-grey sandstone from a shaft put down near Coleraine by the Portland Coal Search Committee (Coleraine No. 1 shaft near Section 21, Coleraine Township; Selwyn, 1863, p. 17). The mussel was given the manuscript name of *"Unio dacombii"* by McCoy (Selwyn, 1861, p. 186; 1862, p. 13; 1867, p. 20) and its presence was considered to confirm a Mesozoic age for the beds. Unfortunately, although allusions were made to the forthcoming publication of figures and descriptions of this fossil (Selwyn, 1862, p. 13), these were apparently never published.

From a second shaft put down in search of coal in 1862 (Coleraine No. 2 shaft, Section 21, Coleraine Township; Selwyn, 1863, p. 17) Dacomb reported finding *"Taeniopteris Daintreei"* in the shales occurring between 17 ft. and 40 ft. In 1867 Selwyn (1867, p. 20) recorded the occurrence of *"Sphenopteris, Pecopteris, Zamites,* and *Taeniopteris"* in the beds intersected by these shafts. *"Taeniopteris spatulata* McClelland" from Coleraine, referred to by Chapman in 1908 (p. 215), probably also came from one of these shafts.

F. M. Krausé's catalogue of specimens sent to the 1886 Colonial and Indian Exhibition in London contained the following records (Krausé, 1886, pp. 78, 79):

"Pecopteris australis" and *"Taenipoteris Daintreei"* from calcareous shales on the Wannon River near Sandford; *"Taeniopteris Daintreei"* from ferruginous shales on the Glenelg River at Warrock; *"Taeniopteris, Sphenopteris, etc."* from sandy ferruginous shale on the Glenelg River at Roseneath; and *"Taeniopteris, Zamites* and *Zingophyllites"* from calcareous shale at Coleraine. Decomposed brecciated shale from a locality in a railway cutting on the left (east) bank of the Glenelg River at Casterton yielded "fragments of *Taeniopteris,* the homocercal tail of a ganoid fish (?leptolepis)," and "a large portion (neural plate) of the carapace of a cheïone". Of the Casterton specimens Krausé remarks: "These fossils tend to show that the Glenelg and Wannon beds are the lowest of the Mesozoic series of Victoria." The specimens in Krausé's collection were presented after the exhibition to the Museum of the Geological Society of Great Britain, London, and duplicates were stated to have been presented to the Mines Department, Melbourne.

Later (1894, p. 395; 1901, p. 15) Dennant recorded the cycad *"Otozamites"* from the Mesozoic at Mount Koroite, Coleraine (see also Hogg, 1899, p. 98; Skeats, 1909, p. 204; Summers, 1912, p. 139).

None of these early fossil records (1861-1894) are accompanied by figures or descriptions. The first formal descriptions of fossils from the Merino Group appeared in 1899 when T. S. Hall described the fossil fish *Psilichthys selwyni* Hall from Carapook, and *Leptolepis crassicauda* Hall from the railway cutting on the left bank of the Glenelg River at Casterton (Krausé's fossil fish locality). Hall regarded the fish as indicating a Triassic or Jurassic age for the beds. *Taeniopteris* sp. ind. and *Baiera* sp. were also described from the Carapook fossil fish beds (Dun, 1899).

Chapman (1908, p. 215) examined a large number of specimens of Victorian *Taeniopteris*, including specimens from Coleraine and Murndal, and concluded that all were variants of *"Taeniopteris spatulata* McClelland". In 1909 he recorded *"T. spatulata* var. *daintreei", Taeniopteris* sp., *"Sphenopteris ampla"*, plant remains indet., and fragments of carbonized wood, from soft carbonaceous shales at Merino Creek, Merino (Chapman, 1909, p. 109).

Very little was added to our knowledge of the fossils of the Merino Group until the appearance of a paper by Cookson (1953) describing the microspore content of Mesozoic sediments from a bore at Comaum, South Australia (Section 222, Hundred of Comaum). Samples of grey mudstone taken from the bore at depths of 650 ft. and greater contain a Mesozoic microflora lacking angiosperm pollen. This microflora is regarded as indicating a Jurassic age.

Medwell (1954a) has recently reviewed the flora of the Victorian Jurassic, and refers most of the recorded species of *Taeniopteris* to *T. spatulata* Oldham and Morris (non McClelland); and of *Sphenopteris* to *S. hislopi* Oldham and Morris. From collections in Victorian museums she identifies *Ginkgoites australis* (McCoy) Florin, and *Taeniopteris spatulata* from Murndal; *T. spatulata* and *Sphenopteris hislopi* from the Coleraine No. 1 shaft; and *T. spatulata* from the Coleraine No. 2 shaft.

The stratigraphic positions of most of these localities cannot be ascertained at present, but as the localities are widely spaced, considerable thicknesses of beds may intervene between the various fossil horizons. In addition, many of the fossil assemblages are small and inconclusive as to age, so that the beds at only a few localities can be regarded as of proved Jurassic age. Nevertheless, approximate equivalence of age of the Mesozoic sediments throughout the State (excluding the Triassic of Bacchus Marsh and Campbelltown) has been generally assumed, and determinations based chiefly on fossil collections from localities in the South Gippsland area (reviewed Skeats, 1935, p. 126; Edwards and Baker, 1943, p. 214) have in general favoured a Jurassic age. Medwell (1954a) places most of the beds in the Lower Jurassic. In view of the occurrence of Cretaceous sediments in the Merino Group these correlations of age over great distances and thicknesses of beds must be regarded as tentative only.

NEW AGE EVIDENCE

Fossils

In the course of reconnaissance mapping carried out during May 1951 at Killara Bluff, seven miles south of Casterton, well-preserved fossil leaves were found in mudstones at two horizons near the top of the Merino Group (see Table 1)

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TABLE 1.—*The succession at the Killara Bluff landslip (see Plate 1)*

Age	Rock Unit	Lithology and Typical Fossils	Thickness	
Holocene	Soil	Red-brown loam with abundant buckshot gravel in the B horizon.		1' 6"
	UNCONFORMITY			
Lower Pliocene (?)		Massive, yellow-brown quartz sand, traversed by numerous irregular veins of limonite. Impersistent bands of coarse quartz sand and lenses of conglomerate (containing pebbles of quartz, of the Bahgallah Formation, and of the Merino Group); and polished black ferruginous(?) nodules) occur at and near the base.		12'
Lower Eocene and/or Palaeocene	Bahgallah Formation	Yellow-brown to brown granular clays, sandy clays, and sands (oxidized glauconitic sediments) with occasional beds of white sandy silt. Shelly fossils include: *Nuculana pauciyradata*, *Cucullona psephea*, *Eotrigonia* sp., *Lahillia australica*, *Panopea* sp., *Aturoidea distans*, etc.	22'	53'
		Brown sands, coarse sands ('grits'), and occasional thin bands of gravel; with interbedded white to grey micaceous sandy silts. A 10 in. bed of fine conglomerate (containing pebbles of quartz and Runnymede Formation(?); fragmentary corals, pelecypods, and fossil wood) occurs about 6 in. from the base. Fragmentary marine shells and *Callianassa* burrows also occur in the upper part of this member.	31'	
	UNCONFORMITY			
Lower Cretaceous	Rumnymede Formation	Blue-grey to white laminated, generally non-fissile mudstones (claystones and siltstones) with a few thin beds of friable, fine-grained felspathic sandstone. Fossil flora (F4) includes *Phyllopteroides lanceolata*, *Sphenopteris* cf. *S. burrumensis*, and dicotyledonous leaves. One specimen of fresh-water pelecypod (undet.) recorded.	24'	65'
		Light-grey to white friable, fine-grained, felspathic sandstone, with interlaminated mudstone in the upper 12 feet. Cross-bedded in the lower part of the member. Rounded pebbles of mudstone occur sporadically.	41'	
	DISCONFORMITY			
Upper Jurassic (?)	Mocamboro Member	Blue-grey to white laminated non-fissile mudstones (claystones and siltstones) and dark-grey to reddish-brown carbonaceous mudstones. Fossil flora (F3) includes *Phyllopteroides dentata*, *P. expansa*, *Taeniopteris spatulata*, etc. Vertical and sub-vertical root-like casts common.		24' +

CAINOZOIC

MESOZOIC

MERINO GROUP (upper part)

by Mr. D. Spencer-Jones and the writer, and were submitted for examination to Miss L. M. Medwell. Later (October 1951) collecting by Mr. A. N. Carter and the writer led to the discovery by Mr. Carter of a dicotyledonous leaf in the higher mudstone horizon (Runnymede Formation). Miss Medwell has since recognized a fragment of another angiosperm in the original collection and has described the flora of these beds in detail (Medwell, 1954b). Angiosperms have not previously been recorded from the Victorian Mesozoic.

The association of undoubted dicotyledons with typical Mesozoic leaves such as *Phyllopteroides* Medwell spp. (= *Phyllopteris* Walkom) and *Sphenopteris* cf. *S. burrumensis,* in Merino beds which unconformably underlie marine sediments assigned (Kenley, 1951) to the Palaeocene or Lower Eocene, points to a probable Cretaceous age for these beds. In other parts of the world the earliest records of definite angiosperm leaves are from Lower Cretaceous (Aptian) rocks (Berry, 1911; Ball, 1937; Walkom, 1919, etc.), although several authors draw attention to the advanced stage of specialization in described Lower Cretaceous forms, and the probability that they had a long developmental history.

The following determinations of new collections of fossil plants from Merino beds have been made by Miss Medwell (1954 a, b):

F1.   Locality: Railway cutting, east side of Glenelg River, Casterton (fossil fish locality of Krausé and Hall). Latitude 37° 35′ 35″ S., Longitude 141° 24′ 42″ E.

      Sphenopteris hislopi Oldham and Morris
      Taeniopteris spatulata Oldham and Morris
      Ginkgoites australis (McCoy) Florin
      Brachyphyllum gippslandicum McCoy

Age: Lower Jurassic.

F2.   Locality: Cliff section, Allotment 29A, Parish of Bahgallah. Lat. 37° 39′ 54″ S., Long. 141° 18′ 15″ E.
Horizon: About 10 feet from the top of the section.

      Phyllopteroides expansa (Walkom) Medwell
      P. dentata Medwell
      ?*Czekanowskia*

Age: ?Upper Jurassic.
Remarks: This flora is compared with F3.

F3.   Locality: Scar of large landslip, Killara Bluff; Allotment 4, Section A, Parish of Killara. Lat. 37° 40′ 53″ S., Long. 141° 21′ 6″ E.
Horizon: Mocamboro Member (see Table 1).

      Phyllopteroides dentata Medwell
      P. expansa (Walkom) Medwell
      Taeniopteris spatulata Oldham and Morris
      Sphenopteris sp.
      Brachyphyllum sp.

Age: Upper Jurassic or Lower Cretaceous.

Remarks: This flora is poor in genera and species, and leaf impressions of *Phyllopteroides* predominate.

F4.   Locality: Same as F3.
        Horizon: Mudstone member of the Runnymede Formation (see Table 1).

> *Phyllopteroides lanceolata* (Walkom) Medwell
> *Sphenopteris* cf. *S. burrumensis* Walkom
> ?*Czekanowskia*
> *Phoenicopsis elongatus* (Morris) Seward
> *Araucarites cutchensis* Feistmantel
> Angiosperm
> ?Angiosperm

Age: Lower Cretaceous. This flora is compared with the floras of the Burrum Series and Styx River Series of Queensland.

Remarks: Leaf impressions and other plant remains are abundant in these mudstones and further careful collecting should add to the flora. Fragments of a freshwater pelecypod have also been found in these beds.

Stratigraphy of the Upper Part of the Merino Group

The beds containing the Upper Jurassic and Lower Cretaceous floras (F3 and F4) are exposed in the scar of a large landslip near the western end of Killara Bluff, and are stratigraphically the highest representatives of the Merino Group yet recognized (see Table 1).

Mocamboro Member. The older flora (F3) was collected from bluish-grey to white mudstones near the base of the landslip scar. These mudstones are part of a formation which is incompletely exposed and cannot be precisely defined at the present time. For the purpose of reference they are tentatively given the name of Mocamboro Member, after the neighbouring parish of Mocamboro.

Leaf impressions are common in these beds, and *Phyllopteroides* leaves have been found to within half an inch of the contact with the overlying felspathic sandstone which forms the lower part of the Runnymede Formation. The mudstones are generally thinly laminated, but tend to break with a conchoidal fracture, making collection of complete specimens of the fossil leaves difficult. Pieces of carbonized wood and other plant fragments abound, and in some beds the carbonaceous material imparts a reddish-brown colour to the rock. Vertical and sub-vertical casts of root-like structures ranging from fine threads to half an inch in diameter also occur in the mudstones, but are truncated at the contact with the overlying sandstones.

The Mocamboro Member-Runnymede Formation contact is marked by a thin deposit of limonite and cuts across the laminations and beds in the Mocamboro mudstone at a low angle, although dips in the two formations are very close. Small cracks (?mud cracks) in the top four inches of the Mocamboro mudstone are filled with felspathic sand containing angular fragments of mudstone apparently derived from the Mocamboro Member. The evidence suggests that the Mocamboro mudstones were exposed at the surface for a brief period whilst they were still in an unconsolidated condition. Mud cracks were developed, and vegetation (presumably swamp plants) was probably established before further inundation, accompanied by some contemporaneous erosion, initiated the Runnymede sedimentation. The Mocamboro Member-Runnymede Formation contact is therefore best regarded as a disconformity, and as the Mocamboro Member is probably of Upper Jurassic age and the Runnymede Formation of Lower Cretaceous age

(Medwell, 1954b), this disconformity has been taken as marking the Jurassic-Cretaceous boundary. The break in sedimentation may indicate that small-scale earth movements occurred in south-western Victoria at about the time of the epi-Jurassic folding in New Zealand.

Runnymede Formation. The Mocamboro Member is disconformably overlain by about 40 feet of light-grey to white, friable, fine-grained, felspathic sandstone (arkose). Much of the sandstone is laminated horizontally, but in the lower part of the bed cross-bedding is prevalent. Rounded mudstone pebbles are distributed sporadically through the sandstone. Towards the top this sandstone grades upwards through a zone of interbedded thin sandstone and mudstone beds into blue-grey to white laminated mudstones which bear a strong lithological resemblance to the mudstones of the Mocamboro Member. The mudstones comprise soft claystones and siltstones, and occasional beds of friable fine-grained felspathic sandstone. Some of the beds show small-scale cross-bedding and slump structures. Plant fragments, many of which are carbonized, are present throughout the strata; but well-preserved leaf impressions are practically restricted to a few horizons in the mudstones.

This sequence of beds overlying the Mocamboro Member forms a well-defined unit which has been named the Runnymede Formation after Runnymede Station, in which the type section occurs (scar of large landslip, Killara Bluff; Latitude 37° 40′ 53″ S., Longitude 141° 21′ 6″ E.).

Lithologically the Runnymede Formation and Mocamboro Member are similar to the Merino Group beds occurring lower in the same section and in other parts of the area; and in the field it is clear that all of these beds belong to the same rock group. A sharp lithological break occurs at the unconformable contact of the Runnymede Formation with the overlying marine Tertiary sediments of the Bahgallah Formation.

The Runnymede and Mocamboro beds can be traced for short distances to the east of the large landslip at Killara Bluff, and to the north in the parish of Bahgallah. Their relations to the undoubted Jurassic beds of the Casterton railway cutting are not known accurately, but they are probably several hundred feet stratigraphically higher in the sequence.

In general, however, exposures of the Merino beds are small, isolated, and of small vertical extent, and it is doubtful if an acceptable sub-division of the greater part of the Group will be possible without extensive boring. The occurrence of Lower Jurassic, Upper Jurassic (?) and Lower Cretaceous sediments in the Merino Group indicates that the Mesozoic section in south-western Victoria is more complete than was previously recognized.

Stratigraphic Relations of the Merino Group

At the north-eastern edge of the main area the Merino beds rest with angular unconformity on Palaeozoic (?Cambrian to Upper Carboniferous-Lower Permian) sedimentary, metamorphic and igneous rocks (Krausé, 1886, pp. 79, 80; Dennant, 1885-6, p. 102; Stirling, 1898, Sect. 5; Fenner, 1918), and fine conglomerates containing pebbles of some of these older rocks are locally developed near the base of the Group.

In the scar of the large landslip at Killara Bluff the Runnymede Formation at the top of the Merino Group is overlain with minor intersection of the beds by the basal ferruginous sand and fine conglomerate ("gravel") of the Bahgallah

Formation (Table 1; Pl. 1, fig. 3). The conglomerate is about 10 in. thick and is situated about 6 in. from the contact. It consists chiefly of rounded quartz pebbles (up to 1 in., but mostly $\frac{1}{4}$-$\frac{1}{2}$ in. in diameter) and contains small pebbles of laminated light-blue mudstone which are probably derived from the Runnymede Formation. Poorly preserved corals and pelecypods in the conglomerate indicate that marine conditions obtained from the very beginning of Bahgallah sedimentation. The basal conglomerate is surmounted by ferruginous sands and grits with intercalated micaceous sandy silts and occasional thin gravel bands. These in turn grade upwards into ferruginous sands and granular clays, in which the fossils *Nuculana paucigradata* F. A. Singleton, *Cucullaea* (*Cucullona*) *psephea* F. A. Singleton, *Eotrigonia* sp. nov., *Lahillia australica* F. A. Singleton, *Panopea* sp., *Aturoidea distans* Teichert, etc., have been found, indicating a Palaeocene or Lower Eocene age for the beds (Kenley, 1951). Bahgallah beds in an unoxidized condition have recently been found in the bed of the Glenelg River downstream from Killara Bridge, where they are glauconitic sands (greensands), and clays.

The Merino Group-Bahgallah Formation contact is exposed in at least two other places in this area. One of these is at the western extremity of the Bahgallah Bluff (Allotment 37A, Parish of Bahgallah), on the north side of the Glenelg River, where the relations are essentially the same as at Killara Bluff; and the other is about 11 chains south-west of Runnymede Homestead where the uppermost Merino beds are friable felspathic sandstones. At each of the three localities the two formations have similar low dips, and weathered zones or channels in the surface of the Merino sediments appear to be absent. Well-preserved fossil leaves have been found about a foot below the unconformity at Killara Bluff. However, the presence of small pebbles of the Runnymede Formation in the basal conglomerate of the Bahgallah Formation indicates that a period of erosion intervened between the deposition of the uppermost beds of the Runnymede Formation and the lowest beds of the Bahgallah Formation. As the date of uplift of the Runnymede Formation is not known precisely, the duration of this period of erosion in south-western Victoria cannot yet be ascertained.

Upstream from the Killara Bluff landslip the Bahgallah beds are unconformably overlain by the bryozoal limestones of the Sandford limestone (Janjukian), at the base of which is a well-defined phosphatic nodule bed. Although these limestones appear to dip concordantly with the underlying Bahgallah Formation, mapping has shown that the contact is an irregular surface. Further upstream these limestones locally overlap the Bahgallah Formation and rest directly on the Merino Group at Sandford Bluff and Roseneath.

Between Casterton and Coleraine the Merino Group is immediately overlain by the thin Cainozoic sediments which bear the fossil lateritic soils of the tablelands (Hills, 1939, p. 302; Blackburn and Leslie, 1949, p. 5). The age of most of these Cainozoic sediments has not yet been established.

Lithology of the Merino Group Sediments

The principal lithological types in the Victorian Jurassic sediments have been described in detail by Edwards and Baker (1943). The sediments of the Merino Group consist chiefly of interbedded mudstones and medium- to fine-grained felspathic sandstones (arkoses). Mudstones are the predominant rock type (cf. Dunn, 1912, p. 114; Edwards and Baker, 1943, p. 198), but owing to the prevailing softness of the beds the proportion of mudstone present tends to be somewhat

exaggerated in field observations. The mudstones are frequently carbonaceous and contain occasional seams of impure black coal ranging from thin films to about two feet in thickness. Comminuted plant remains, many of which are carbonized, are present throughout the beds.

The sandstones are generally a dark greenish-grey in colour when fresh, but weather rapidly to a light greenish-grey, light brown, or ash-grey on exposure at the surface. The mudstones show a similar change from blue-grey (fresh) to buff or white on weathering. The unweathered sandstones owe their colour to the abundant chlorite cementing the detrital constituents of the rock (Edwards and Baker, 1943, p. 200). Notwithstanding this chlorite cement, the Merino sediments are generally less lithified than the Jurassic sediments in other parts of the State, and many of the sandstones are friable even when apparently fresh. The chlorite cement is replaced by secondary carbonate in some of the sandstone beds and in the 'cannonball' concretions (cf. Edwards and Baker, 1943). Pyrite is occasionally present in the sandstones (Selwyn, 1867, p. 17), and crystals up to half an inch in diameter were present in percussion drill chippings from a depth of about 300 feet in a bore at the Merino Consolidated School (Allotment 5, Section 111, Parish of Merino).

Intraformational breccia beds 6 in. to 1 ft. 6 in. thick containing pebbles of mudstones and sandstone, and some, fragments of coalified wood, have been observed at Casterton and Tahara. Isolated mudstone pebbles in some of the sandstones were probably also formed by contemporaneous erosion (cf. Edwards and Baker, 1943, pp. 212, 213). Small pebble lenses comprising pebbles of quartz, slate, and spotted slate (comparable with slates in the Dunrobin area) occur in sandstones in the cliff sections west of the Runnymede Homestead. Conglomerates have been recorded from bores at Merino and Muntham (Department of Mines, Victoria, 1938; Merino No. 7, pp. 41, 42; Muntham No. 1, p. 29), and beds of fine conglomerate containing pieces of carbonized wood, and pebbles of reef quartz, slate and sandstone, occur near the base of the Group at Nangeela, four miles north-north-west of Dunrobin. The pebbles are derived from the underlying Ordovician(?) bedrock.

The sandstone forming the lower part of the Runnymede Formation appears to be fairly representative of the Merino Group sandstones and conforms in most respects with the generalized descriptions of the Victorian Jurassic arkoses given by Edwards and Baker (1943). In thin section it is seen to consist of sharp, angular grains of quartz and acid felspar, flakes of biotite, and abundant sub-rounded to rounded rock fragments (mostly of intermediate(?) lava). These grains are cemented by pale-green chlorite which makes up about 25 per cent of the rock. The felspar grains are generally clear and consist predominantly of orthoclase together with a little oligoclase. On size analysis the sand grains in a typical specimen were found to range in size from about 1·5 mm. down to the lower limit of the sand size range (0·06 mm.), but 62 per cent of the grains were between 0·4 and 0·15 mm.

Sedimentary Structures

Cross-bedding is common in the sandstones and is also present on a small scale in the more fine-grained sediments. The sandstone beds are commonly lenticular, but in places individual beds appear to persist for some distance both parallel and normal to the strike. Channelling of the upper surface of beds has been observed in a number of localities.

B

As in the Jurassic rocks in other parts of the State, epigenitic "cannonball" concretions are common in the sandstones of the Merino Group. They are hard sub-spherical concretions ranging from about 6 in. to 3 ft. in diameter, in which the sand grains are cemented by secondary carbonate (cf. Edwards and Baker, 1943, p. 207). Cigar-shaped concretions, probably of a similar origin, are common in part of the Killara Bluff.

Conditions of Sedimentation

Edwards and Baker (1943) have shown that the Jurassic arkoses are of uniform composition throughout, and conclude that the various Victorian Jurassic deposits were originally laid down in the one lacustrine basin of deposition. As evidence of long stratigraphic breaks or marine intercalations is at present lacking, they consider that this basin persisted throughout the entire period of sedimentation. The lake waters are thought to have been generally shallow, subsidence having kept roughly apace with deposition. The prominent cross-bedding and frequent signs of contemporaneous erosion in the sediments are taken to indicate that strong currents were prevalent and that fluctuations of water level probably occurred which may at times have exposed the lake floor.

Conditions do not appear to have been generally suitable for the growth of plants within the lake waters, and plant debris in the sediments is almost entirely of drift origin (Edwards and Baker, 1943, p. 214); but the presence of fossil root-lets in the Merino Group at Killara Bluff (Mocamboro Member) and in mudstones exposed in a road cutting about one mile north-east of Merino on the Coleraine-Merino road (east side of Allotment 22A, Merino Township) indicates that at certain times plants grew *in situ* within the lake area in the south-west. This implies the existence, at least temporarily, of shallow water or terrestrial conditions. Sand-filled cracks (?mud cracks) at the top of the Mocamboro Member also indicate temporary exposure of the sediments at the surface. From the small outcrops available it is difficult to determine whether these features are due to small fluctuations of water level in the vicinity of the lake edge, or to the more general effects of earth movements.

The abundance of fresh angular felspar in the arkoses, and the presence of well-preserved remains of fragile plants in some of the mudstones indicate that the sediments were deposited rapidly (Edwards and Baker, 1943, p. 220). Vigorous erosion of the Mesozoic terrain and subsequent rapid deposition of detritus in the adjoining lake gave rise to the beds of arkose and occasional lenses of conglomerate; but as mudstones are the dominant lithological type in the south-west, it seems that sedimentation was less rapid in this part of the State than elsewhere in the Mesozoic sedimentary basin.

Structure of the Merino Group Area

The beds of the Merino Group are generally flat-lying or gently dipping; but locally the dips attain values of up to 15°. The higher dips are generally thought to be associated with faults (Skeats, 1935, p. 126); but because of the poor exposures, faults without topographic expression at the present time are rarely observed. Dips in the Runnymede Formation at Killara Bluff are very low and probably do not exceed 3°.

A description of the structural pattern of south-western Victoria has been given by Boutakoff (1952), and most of the faults shown in the map (fig. 1) are based

on his work. In addition to the faults he describes, there may also be a fault or monoclinal flexure along part of the north-east side of the triangle of Merino Group sediments, where the Merino strata abut on the complex of Palaeozoic rocks to the north. Dunn (1912, p. 114) observed that the Jurassic beds do not "extend much to the north of a line drawn from Hamilton through Coleraine and on to Roseneath"; but the existence of a fault in this position was first postulated in manuscript by Beavis (1947). Beavis observed prevailing dips of 10°-15° N. in Merino beds at Coleraine, a short distance south of outcropping Palaeozoic granites. The tablelands are at markedly different levels on either side of this line—the more elevated tablelands of central Dundas (1,000 ft. to 725 ft. above sea level) occurring to the north, and the lower tablelands of southern Dundas and northern Normanby (650 ft. to 600 ft. and less) to the south. This difference of elevation probably indicates some post-'Dundas laterite' faulting or monoclinal warping; but may also be in part due to gentle upwarping along an east-west axis of the land surface in central Dundas, as suggested by Hills (1939, p. 302; 1940, p. 276).

Evolution of the Present Topography

The greater part of the triangular area of Merino sediments seems to have been above sea level since the time of the withdrawal of the Bahgallah seas, although the south-western and south-eastern flanks of the area were submerged at various times by the advances of later Tertiary seas. At the end of Kalimnan (Lower Pliocene) time there existed a remarkable plain surface in the south-west—a surface relieved only by small isolated residual highlands of resistant rocks (e.g. Dundas Ranges and Mount Cavendish). A veneer of Cainozoic sands and gravels covered much of the plain area, and lateritic soils 10-15 ft. thick (the "Dundas laterites") were formed in these sands over most of the land areas which included County Dundas, the northern part of Counties Follett and Normanby, and adjoining areas in Victoria and South Australia.

The presence of a fossil tortoise which Chapman (1919, p. 12) refers "with some reservation" to the Murray River tortoise, *Emydura macquariae* (Gray), in an ironstone from Carapook has been interpreted as indicating that communication with the Murray by a dominantly fresh-water route was possible up to a comparatively recent time, and that therefore uplift of the Dundas Tablelands is of "fairly recent date" (Hills, 1939, p. 302). However, it seems probable that some of the fault scarps, such as those of the Kanawinka and Weecurra faults, were already in existence in Upper Pliocene time, as these appear to have formed the coastline in the Werrikooian sea (Boutakoff, 1952, p. 6). It therefore appears that the initial breaking up of this plain surface commenced in epi-Kalimnan time (cf. Hills, 1934, p. 166; 1940, pp. 274, 276; Boutakoff, 1952, p. 24) with the formation of an open system of fault blocks bounded by faults of small post-Kalimnan vertical displacement.

Deep valleys were carved in the vicinity of Wannon before extrusion of the Newer Basalts. Basaltic effusions, faulting and warping movements continued intermittently through late Pliocene to Pleistocene and Recent time (Hills, 1934, 1940; Boutakoff, 1952). The rejuvenated streams cut back rapidly from the epi-Kalimnan and younger fault scarps into the upfaulted blocks and quickly established deep gorge-like valleys. In the Merino Group area these valleys were rapidly widened by undercutting of the hard laterite capping and landslipping, thus reducing the size of the tableland interfluves until at present in some places only

small remnants of the original land surface remain. This process of dissection of the tablelands has progressed to a stage of late youth (Hills, 1939, p. 302; 1940, p. 261).

Palaeogeography

The Runnymede Formation has been traced for only short distances and its total distribution cannot at present be assessed. It may represent the deposits of a shrunken remnant of the Victorian Jurassic lake or of an extension of the great Cretaceous lakes of central Australia. However, strong post-Jurassic and pre-Maryborough (Upper Cretaceous) earth movements have not been recognized in Australia so that lakes may also have persisted from the Jurassic into the Cretaceous in other Mesozoic areas of Victoria and the south-eastern part of South Australia.

The probable widespread distribution of marine Palaeocene or Lower Eocene sediments in western Victoria (Baker, 1943, 1950; Kenley, 1951) establishes that downwarping or faulting of the southern part of the Upper Cretaceous terrain was initiated at the close of the Mesozoic era in this area as averred by Hills (1940, p. 271) and Baker (1943, p. 251).

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Explanation of Plate I

Fig. 1.—Killara Bluff from the north-east, looking across the valley of the Glenelg River. From left: Killara Bluff with the large landslip near its western end, the youthful scarp of the Kanawinka fault, the coastal plains of Follett and Normanby. The highest point on the Bluff is about 420 ft. above river level.

Fig. 2.—South face of the scar of the large landslip, Killara Bluff. The positions of stratigraphic breaks (see Table 1) are indicated by dashes. The total height of the cliff is about 160 ft.

Fig. 3.—The Runnymede Formation-Bahgallah Formation contact, Killara Bluff landslip scar. The trace of the contact is indicated by the hammer head, pick head, and right hand of figure. The pick handle is 3 ft. long.